International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 3, pp.118-126, March 2026.
www.ijersem.com eISSN- 3107-9075

# Real-Time Bomb Sensing Robotic Platform with Wireless Video Surveillance

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**Abstract:** Bomb detection and surveillance in hazardous environments require intelligent robotic systems that reduce direct human involvement and improve operational safety. This paper presents the design and implementation of an IoT-based real-time bomb sensing robotic platform integrated with wireless video surveillance using an ESP32 microcontroller. The proposed system incorporates a metal detector for identifying metallic explosive components, an LPG gas sensor for detecting hazardous gases, and a DHT11 sensor for monitoring environmental conditions such as temperature and humidity. A wireless night vision camera enables real-time video streaming for remote monitoring through a mobile-based interface. The robotic platform also includes a motor driver-based navigation system and a robotic arm mechanism for safe handling of suspicious objects. Experimental results demonstrate reliable sensor performance, effective wireless communication, and stable robotic movement during testing. The proposed system provides a cost-effective and efficient solution for surveillance, hazardous environment monitoring, and defence-related applications.

**Keywords:** Bomb Detection, IOT-Based Robotics, ESP32, Metal Detector, Gas sensor.

## 1 INTRODUCTION

Modern defence, security, and emergency-response operations frequently require personnel to work in hazardous environments where the presence of explosive devices, toxic gases, or unidentified suspicious objects poses a serious threat to human safety. Activities such as bomb detection, surveillance of hostile territories, monitoring of suspicious locations, and handling of potentially dangerous objects demand high levels of precision, reliability, and real-time situational awareness. Traditionally, such operations relied heavily on trained bomb disposal squads and manual inspection techniques. Although effective in controlled scenarios, these approaches expose personnel to significant risk and are often limited by environmental constraints, delayed response time, and restricted accessibility in complex terrains [1]. With the rapid advancement of embedded systems, wireless communication technologies, and Internet of Things (IoT)-based automation, robotic platforms have become increasingly important in supporting military and security operations. Intelligent robotic systems equipped with multiple sensors and wireless monitoring capabilities can perform surveillance and detection tasks remotely while minimizing direct human involvement [2].

These systems not only improve operational safety but also enhance efficiency by enabling continuous monitoring and faster response during emergency situations. As a result, IoT-enabled robotic surveillance platforms are gaining considerable attention in modern defence infrastructure and homeland security applications. Several research efforts have focused on the development of wireless surveillance robots capable of remote navigation and real-time monitoring. These systems typically integrate camera modules and communication interfaces that allow operators to observe hazardous environments from a safe location. However, many existing robotic platforms primarily emphasize visual surveillance and movement control while lacking integrated sensing mechanisms required for reliable bomb detection. In addition, certain systems rely on single-sensor detection approaches, which reduces reliability in practical field environments where multiple environmental parameters must be monitored simultaneously [3]. The absence of robotic manipulation mechanisms in several surveillance robots further limits their ability to safely handle suspicious or explosive objects once detected.

Another important limitation observed in many existing defence robotic platforms is the lack of compact, low-cost, and energy-efficient implementations suitable for practical deployment in resource-constrained environments. Advanced autonomous bomb disposal robots often involve complex artificial intelligence algorithms and expensive sensing technologies, which increase system cost and computational requirements [4]. Therefore, there is a strong need for a cost-effective, multi-sensor-enabled robotic platform capable of performing real-time bomb detection assistance along with wireless surveillance and object-handling capability. To address these limitations, this paper proposes the design and implementation of a real-time bomb sensing robotic platform integrated with wireless video surveillance using an ESP32-based embedded control architecture.

The proposed system combines multiple sensing modules, including a metal detector for identifying metallic explosive components and hidden landmine-like objects, an LPG gas sensor for detecting flammable or hazardous gases present in the surrounding environment, and a DHT11 sensor for monitoring environmental temperature and humidity conditions [5]. The integration of multiple sensors improves detection reliability and enables the system to respond effectively under varying environmental conditions. In addition to sensing capabilities, the robotic platform incorporates a wireless IP camera that provides continuous real-time video streaming to a remote monitoring station through Wi-Fi communication. This feature allows operators to visually inspect suspicious environments from a safe distance and supports decision-making during surveillance and bomb-handling operations [6].

The mobility of the robot is achieved through DC motors controlled using an L293D motor driver interface, enabling smooth navigation in forward, backward, left, and right directions across different terrains. A robotic arm mechanism is also integrated into the system to enable safe picking, lifting, and placement of suspicious metallic objects under remote supervision, thereby reducing direct human exposure to hazardous materials. The ESP32 microcontroller acts as the central processing unit of the robotic platform by coordinating sensor data acquisition, motor control operations, wireless communication, and system monitoring functions. The platform operates using a rechargeable battery power supply, ensuring portability and uninterrupted operation during field deployment. The integration of sensing, surveillance, wireless communication, and robotic manipulation features into a single compact platform makes the proposed system suitable for real-time deployment in defence applications, border surveillance, bomb detection assistance, and disaster-response environments. The main contributions of the proposed system can be summarized as follows [7].

First, a multi-sensor-based detection mechanism is implemented by integrating metal detection, gas sensing, and environmental monitoring modules into a single robotic platform to improve detection reliability. Second, a wireless real-time video surveillance system is incorporated to provide continuous visual feedback to remote operators during hazardous operations. Third, a robotic arm mechanism is introduced for safe handling and relocation of suspicious objects without direct human intervention. Finally, an ESP32-based IoT communication architecture is designed to enable efficient real-time monitoring and remote control with low cost and reduced computational complexity. By combining these features into a unified embedded robotic system, the proposed platform significantly enhances operational safety, improves situational awareness, and provides an efficient and economical solution for assisting bomb detection and surveillance tasks in modern military and security environments.

## 2 Related Work

Recent advancements in robotics and Internet of Things (IoT) technologies have significantly improved the capabilities of intelligent surveillance systems operating in hazardous and safety-critical environments. Researchers have focused on developing autonomous robotic platforms capable of performing monitoring and inspection tasks while minimizing direct human involvement. For instance, Tooki *et al.* [1] developed an intelligent telemetry-based hexapod robotic system for surveillance of power system components, demonstrating the effectiveness of integrating wireless telemetry communication and multi-legged robotic mobility for remote monitoring applications in complex environments. Similarly, Tamilselvi *et al.* [2] proposed an IoT-enabled energy-efficient flying robot designed for agricultural field monitoring using smart sensor networks. Their work highlights the importance of integrating wireless sensing technologies and real-time environmental monitoring mechanisms into robotic platforms, which can also be extended to surveillance applications in hazardous environments.

Arjun and Suresh [3] presented an IoT-based multifunctional robot for military applications capable of performing remote surveillance and navigation using wireless communication technologies. Although their system improved battlefield monitoring capability, it lacked advanced multi-sensor integration and object-handling mechanisms required for reliable bomb detection applications. Robotic automation has also been widely explored in industrial safety-critical sectors. Obosu and Frimpong [4] reviewed the role of robotics in mining automation and emphasized the importance of intelligent robotic systems for reducing human exposure in hazardous operational environments. Their study confirms the growing significance of robotic assistance in environments where manual inspection involves considerable safety risks. Mobile surveillance robots controlled through wireless interfaces have also been investigated for real-time monitoring applications.

Azeta *et al.* [5] developed an Android-based mobile robot capable of performing monitoring and surveillance tasks using wireless communication and camera-based observation systems. While effective for remote visual inspection, their system did not incorporate environmental hazard detection capabilities required for defence-oriented robotic platforms. Accurate localization is another essential requirement for robotic systems operating in dynamic environments. Ullah *et al.* [6] presented a comprehensive review of mobile robot localization techniques and highlighted several challenges affecting navigation reliability in real-world scenarios. Their findings emphasize the importance of combining sensing and communication technologies for improving navigation accuracy in surveillance robots. Recent developments in the Internet of Robotic Things (IoRT) have enabled improved interoperability between sensing modules and robotic platforms. Yaacoub *et al.* [7] discussed the concept of modular robotic things and identified challenges related to scalability, communication efficiency, and integration flexibility in IoRT-enabled robotic systems.

These advancements support the development of intelligent robotic platforms capable of performing distributed monitoring operations in complex environments. Machine learning techniques are increasingly being integrated with robotic manipulation systems to improve object handling capability and adaptive decision-making performance. Nahavandi *et al.* [8] presented recent advances in machine learning-based robotic manipulation and demonstrated how intelligent control strategies enhance robotic interaction with physical objects in uncertain environments.

Hybrid robotic mechanisms combining mobility and manipulation functions have also been explored extensively. Ben-Tzvi *et al.* [9] proposed an articulated hybrid mobile robot mechanism capable of performing navigation and manipulation tasks using onboard wireless sensor and actuator interfaces, highlighting the effectiveness of integrating sensing and actuation within a unified robotic architecture. Power management plays a critical role in ensuring reliable operation of autonomous robotic platforms during long-duration surveillance missions. Farooq *et al.* [10] reviewed various power supply solutions for autonomous mobile robots and emphasized the importance of efficient battery-based energy systems for improving operational sustainability in field deployments. Innovative robotic structural designs have also been investigated for adaptable movement in constrained environments. Li *et al.* [11] introduced a soft active origami robot capable of flexible motion and structural transformation, demonstrating the potential of lightweight robotic architectures for future rescue and surveillance operations. The integration of artificial intelligence with Internet of Robotic Things architectures further enhances robotic coordination and behavioural prediction capabilities.

Liu *et al.* [12] analysed robotic behaviour modelling in smart city environments using reinforcement learning and imitation learning techniques within IoRT frameworks, highlighting the role of intelligent decision-making in next-generation surveillance systems. Swarm robotics represents another promising research direction for distributed monitoring tasks. Tan and Zheng [13] reviewed recent advances in swarm robotic systems and demonstrated their effectiveness in cooperative surveillance operations across large-scale environments, although such systems introduce additional communication complexity compared to single-platform robots. Artificial intelligence-based visual perception has also become an essential component of modern mobile robotic systems.

Cebollada *et al.* [14] presented a comprehensive review of mobile robotics tasks using artificial intelligence and visual data processing techniques and emphasized the importance of integrating intelligent vision systems for improving surveillance accuracy and environmental awareness. Despite these advancements, many existing robotic surveillance platforms still lack integrated multi-sensor detection capability combined with real-time wireless monitoring and robotic manipulation features required for safe bomb detection assistance. Therefore, the proposed IoT-based real-time bomb sensing robotic platform integrates environmental sensing, wireless surveillance, and robotic object-handling mechanisms into a unified embedded architecture to improve safety and operational efficiency in hazardous environments.

## 3 METHODOLOGY

The proposed system is designed to address the shortcomings of existing military robots by introducing an IoT-based, multi-functional robot that can detect bombs, monitor surroundings, and safely handle or dispose of dangerous objects. The robot is equipped with several sensors, a wireless camera, and a robotic arm, all controlled by a single embedded unit. This allows the system to sense the environment in real time, transmit live visual information to a remote operator, and physically interact with hazardous objects when required. By enabling remote monitoring and controlled robotic actions, the system minimizes direct human involvement in risky military and security operations, thereby improving safety and operational efficiency. Fig. 1 shows the block diagram of the proposed IoT-based bomb detection robotic system.

The sensor data collected from the robot is continuously analysed as it operates, allowing the system to quickly identify suspicious objects or unsafe environmental conditions. A wireless IP camera fixed on the robot streams live video, giving the operator a clear, real-time view of the area so that the surroundings can be visually examined from a safe location. The movement of the robot is controlled through a motor driver unit that operates the DC motors, enabling the robot to move forward, backward, and turn smoothly in different directions. A robotic arm plays a crucial role in the system by allowing the robot to carefully pick up, lift, and safely place bomb-like or suspicious metallic objects while being controlled remotely by the operator. Communication between the robot and the remote monitoring station is handled through a Wi-Fi–based IoT module, which supports real-time data transfer and control commands. The entire system runs on a rechargeable battery, making the robot portable and capable of continuous operation without the need for a constant external power source.

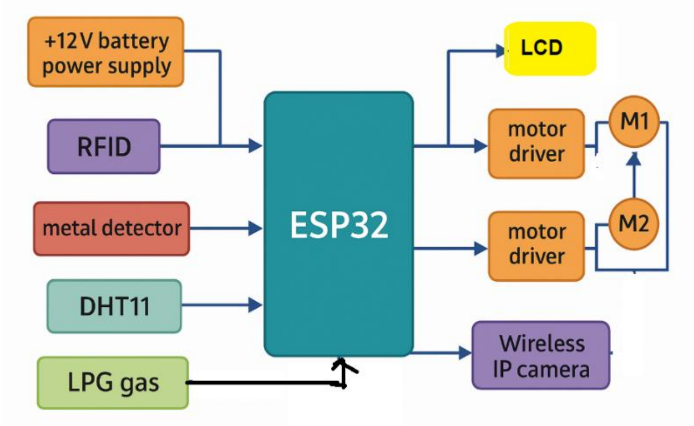


Fig. 1. Block diagram of the proposed IoT-based bomb detection robotic system

**ESP32 Microcontroller:** The ESP32 microcontroller acts as the central processing unit of the proposed robotic platform and coordinates the operation of all integrated hardware components. It processes input signals received from sensors such as the metal detector, gas sensor, and DHT11 environmental sensor for real-time monitoring and decision-making. The ESP32 also controls the motor driver module to enable directional movement and navigation of the robot in hazardous environments. Its built-in Wi-Fi and Bluetooth communication capabilities support wireless data transmission and remote monitoring through IoT-based interfaces. The microcontroller manages the operation of the robotic arm and LCD display for system status indication during surveillance operations. Therefore, the ESP32 plays a critical role in ensuring efficient control, communication, and coordination of the entire robotic system. Fig. 2 shows the ESP32 microcontroller.

Fig. 2. ESP32 Microcontroller

**Metal Detector:** The metal detector shown in Fig. 3 is used to identify the presence of metallic objects that may represent explosive components or hidden hazardous materials in the surveillance area. It continuously scans the surrounding environment and generates detection signals when metallic substances are identified within its sensing range. The detected signal is transmitted to the ESP32 microcontroller for processing and immediate response generation. Upon detection of metal objects, the system provides warning alerts through the LCD display and can automatically stop the robot to avoid unsafe movement. This feature enables early identification of suspicious objects during monitoring operations in sensitive locations. Therefore, the integration of the metal detector significantly enhances the detection capability and safety performance of the proposed robotic platform.

Fig. 3. Metal Detector

**Night Vision Camera:** The night vision camera module, as shown in Fig. 4, is a compact, low-power imaging device used for real-time wireless surveillance and remote monitoring of hazardous environments. It is equipped with an OV2640 camera sensor and an onboard TF card slot for image and video data storage.

The camera captures live video footage and transmits it to the remote monitoring station through the ESP32-based wireless communication interface. Its night vision capability enables effective monitoring even under low-light or dark environmental conditions. This feature significantly improves situational awareness for operators during surveillance operations in restricted or dangerous areas. Therefore, the integration of the night vision camera enhances the effectiveness of the proposed robotic platform for real-time monitoring and inspection applications.


Fig. 4. Night Vision Camera

**Gas Sensor:** The gas sensor as shown in Fig. 5. is used to detect the presence of LPG and other hazardous or flammable gases in the surrounding environment to enhance operational safety during surveillance tasks. It continuously monitors the air quality near the robotic platform and provides real-time detection signals when abnormal gas concentrations are identified. Upon sensing gas leakage, the sensor immediately sends alert information to the ESP32 microcontroller for further processing and warning generation. The detected gas status is displayed on the LCD module to inform the operator about potential environmental risks. This feature enables early identification of explosive or toxic gas conditions in hazardous locations such as confined spaces and military-sensitive zones. Therefore, the integration of the gas sensor significantly improves the reliability and safety performance of the proposed bomb sensing robotic platform.

Fig. 5. Gas Sensor Module

**Power Supply Unit:** The power supply unit shown in Fig. 6. provides the required electrical energy for the operation of the entire robotic platform and its integrated sensing modules. It converts the input electrical energy from rechargeable batteries into regulated voltage levels suitable for the ESP32 microcontroller, sensors, motor driver circuits, and camera module. A stable power supply ensures reliable communication between hardware components and prevents unexpected system interruptions during operation. It also supports continuous functioning of the DC motors responsible for robot movement and navigation in different directions. The regulated output voltage improves system efficiency and protects sensitive electronic components from voltage fluctuations. Therefore, the power supply unit plays a critical role in maintaining uninterrupted and stable performance of the robotic system in field applications.

Fig. 6. power Supply Unit

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www.ijersem.com eISSN- 3107-9075

**Motor Driver:** L293D is a basic motor driver shown in Fig. 7. It is an integrated chip (IC) that enables us to drive a DC motor in either direction and also control the speed of the motor. The L293D is a 16-pin IC, with 8 pins on each side, allowing us to control the motor. It means that we can use a single L293D to run up to two DC motors. These act as an interface between the microcontroller and DC motors. They boost the low-power control signals to drive the motors safely.

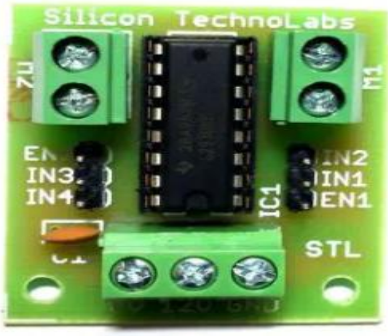


Fig. 7. Motor Driver

## 4 Results and Discussion

The proposed real-time bomb sensing robotic platform with wireless video surveillance was successfully designed, fabricated, and tested under controlled laboratory conditions to evaluate its sensing capability, wireless monitoring performance, and robotic manipulation functionality. The integrated hardware prototype consisting of the ESP32 microcontroller, metal detector module, gas sensor module, night vision camera, LCD display, rechargeable battery unit, and robotic arm mechanism is shown in Fig. 8. The developed system demonstrates stable operation during continuous testing and confirms the effectiveness of integrating multiple sensing modules within a single embedded robotic platform.

Fig. 8. Experimental prototype of the proposed bomb sensing robotic platform

The metal detection functionality of the robotic platform was tested by placing metallic objects near the sensing region of the robot. The metal detector successfully identified the presence of metallic components representing possible explosive materials and immediately transmitted detection signals to the ESP32 controller. Upon detection, the robot automatically stopped its movement to avoid further approach toward the hazardous object, and a warning message was displayed on the LCD interface, as shown in Fig. 9. This confirms that the system can provide early-stage identification of suspicious metallic objects and improve operational safety during surveillance missions.


Fig. 9. LCD display showing metal detection alert message

The robotic arm mechanism integrated into the platform was evaluated for its ability to safely manipulate suspicious objects during remote operation. When the arm opening command was issued through the control interface, the robotic arm successfully executed the movement and the corresponding system status message was displayed on the LCD screen as illustrated in Fig. 10. This confirms that the robotic arm can perform controlled manipulation operations required for handling hazardous objects.


Fig. 10. LCD display showing robotic arm opening operation

Similarly, the robotic arm closing mechanism was tested to verify its gripping functionality. The robotic arm responded accurately to the closing command, and the corresponding confirmation message was displayed on the LCD interface, as shown in Fig. 11. The successful execution of both opening and closing operations demonstrates the reliability of the robotic manipulation subsystem for safe object handling during bomb detection assistance tasks.


Fig. 11. LCD display showing robotic arm closing operation

The LPG gas sensor module integrated into the robotic platform was tested for detecting hazardous gas presence in the surrounding environment. During experimentation, the gas sensor successfully detected flammable gases such as LPG and generated a warning notification through the LCD display as illustrated in Fig. 12. The rapid response of the sensor improves the system's ability to identify potentially dangerous environmental conditions in real time and enhances operational safety during surveillance in enclosed or hazardous areas.


Fig. 12. LCD display showing hazardous gas detection alert

Wireless monitoring and navigation control of the robotic platform were achieved through a mobile-based IoT control interface. The developed mobile application enables the operator to control robot movement in forward, backward, left, and right directions while simultaneously monitoring environmental parameters such as temperature and humidity values transmitted from the DHT11 sensor. The real-time control interface used for robot navigation and monitoring is shown in Fig. 13, which demonstrates the effectiveness of wireless communication between the robot and the remote monitoring station. The night vision camera integrated into the robotic platform was tested to evaluate its performance in real-time wireless surveillance operations under low-light environmental conditions. The camera successfully captured live video streams and transmitted them to the monitoring interface with minimal delay. The experimental setup showing the robotic platform with the integrated night vision camera module is presented in Fig. 14, confirming the effectiveness of the proposed system for remote surveillance in hazardous and low-visibility environments.

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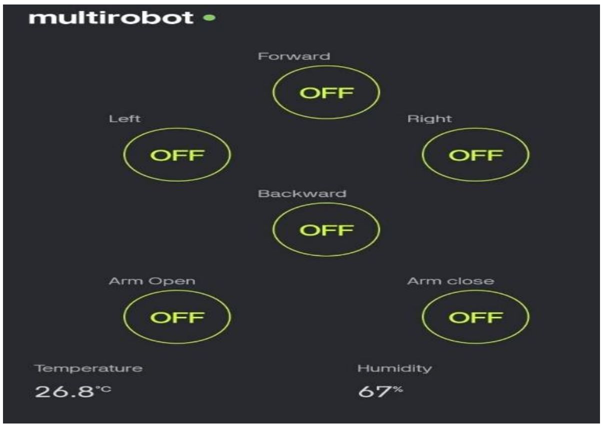


Fig. 13. Mobile application interface for robot navigation and environmental monitoring

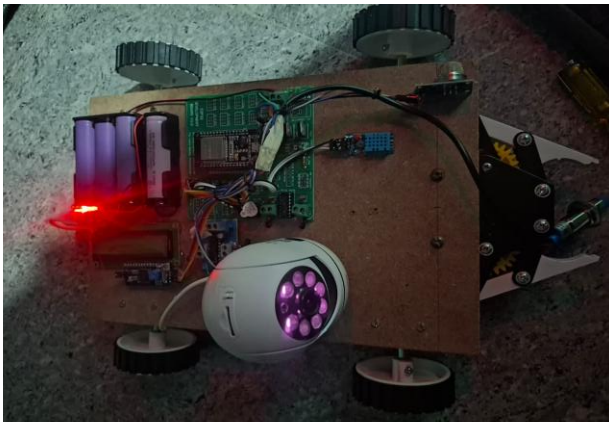

Fig. 14. Robotic platform integrated with a night vision camera for real-time surveillance

## 5 Conclusions

This paper presented the design and implementation of an IoT-based real-time bomb sensing robotic platform with wireless video surveillance for improving safety in hazardous environments. The proposed system integrates a metal detector, gas sensor, temperature and humidity sensor, and night vision camera with an ESP32 microcontroller to enable real-time monitoring and remote operation. The robotic arm mechanism allows safe handling of suspicious objects, thereby reducing direct human exposure to dangerous situations. Experimental testing confirmed reliable detection of metallic objects and hazardous gases along with stable wireless communication and smooth navigation performance. The LCD interface provided real-time system status updates, enhancing operator awareness during monitoring operations. The developed robotic platform demonstrates a compact, portable, and cost-effective solution suitable for defence surveillance and security applications. Future improvements may include GPS-based navigation, artificial intelligence-based object recognition, and autonomous path-planning techniques to enhance system capability and enable fully automated operation in complex environments.

### Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

### Ethics Statement

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

### Statement Of Conflict Of Interests

The authors declare that they have no conflicts of interest related to this study.

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